Information Evaluation: Discussion about STANAG 2022 Recommendations

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1.0 INTRODUCTION

An important step in the intelligence gathering process is the fusion of information provided by several sources. The objective of this process is to build an up-to-date and correct view of the current situation with the overall available information in order to make adequate decisions. Moreover, to succeed in this process, it is important to associate with each available information, some attributes like the number of the sources that support it, their reliability, the degree of truth of the information etc. For the moment, these attributes are managed by the human operator when he fuses information provided by the different sources. However, there is no real methodology to do this in a formal manner. And, when relaying this fusion process to a machine, we need to develop formal definitions and algorithms to manage these attributes in addition to fusing information. Furthermore, in a context of interoperability where different systems exchange information, common definitions of these attributes have to be shared. The Standardization Agreements (STANAG) 2022 of North Atlantic Treaty Organization (NATO) defines a framework for such common definitions.

The purpose of this paper is first to analyze the STANAG 2022 recommendations about information evaluation and then to set a first step in the definition of a formal and non ambiguous system for evaluating information. Indeed, as it will be shown, the present recommendations, written in natural language are rather ambiguous and imprecise and are open to discussion. This paper is organized as follows. Section 2 presents a review of STANAG 2022 recommendations and points out to the main notions that underline these recommendations. Section 3 analyzes the different assumption underlying the evaluation proposed in the STANAG. Section 4, an example of symbolical formalism for the fusion of information is presented. In this example, we consider some of the assumption of STANAG 2002. Finally, section 5 is devoted to a discussion.

2.0 REVIEW OF STANAG 2022 RECOMMENDATIONS

The Annex to STANAG 2022, Edition 8 ([1]) explicitly mentions that the aim of information evaluation is to indicate the degree of confidence that may be placed in any item of information which has been obtained for intelligence. (...) This is achieved by adopting an alphanumeric system of rating which combines a measurement of the reliability of the source of information with a measurement of the credibility of that information when examined in the light of existing knowledge.

Examining the whole text leads us to point out that the two main concepts in this evaluation system are the reliability of the sources and the credibility of the information. These concepts are defined in the STANAG 2022 recommendations, as follows:

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Reliability of the source is designated by a letter between A and F signifying various degrees of confidence as indicated below.

- a source is evaluated A if it is completely reliable. It refers to a tried and trusted source which can be depended upon with confidence.
- a source is evaluated B if it is usually reliable. It refers to a source which has been successfully used in the past but for which there is still some element of doubt in particular cases.
- a source is evaluated C if it is fairly reliable. It refers to a source which has occasionally been used in the past and upon which some degree of confidence can be based.
- a source is evaluated D if it is not usually reliable. It refers to a source which has been used in the past but has proved more often than not unreliable.
- a source is evaluated E if it is unreliable. It refers to a source which has been used in the past and has proved unworthy of any confidence.
- a source is evaluated F if its reliability cannot be judged. It refers to a source which has not been used in the past.

Credibility of information is designated by a number between 1 and 6 signifying varying degrees of confidence as indicated below.

- If it can be stated with certainty that the reported information originates from another source than the already existing information on the same subject, then it is classified as "confirmed by other sources" and rated 1.
- If the independence of the source of any item of information cannot be guaranteed, but if, from the quantity and quality of previous reports, its likelihood is nevertheless regarded as sufficiently established, then the information should be classified as ``probably true" and given a rating of 2.
- If, despite there being insufficient confimation to establish any higher degree of likelihood, a freshyly reported item of information does not conflict with the previously reported behaviour pattern of the target, the item may be classified as ``possibly true" and given a rating of 3.
- An item of information which tends to conflict with the previously reported or established behaviour pattern of an intelligence target should be classified as ``doubtful" and given a rating of 4.
- An item of information which positively contradicts previously reported information or conflicts with the established behaviour pattern of an intelligence target in a marked degree should be classified as ``improbable" and given a rating of 5.
- An item of information is given a rating of 6 if its truth cannot be judged.

The previous definitions of information evaluation can be criticized. Indeed, since they are given in natural language, they are quite imprecise and ambiguous and a lot of points are open to discussion. For exemple, if we consider the credibility of information, it seems that the rating defined according to the recommendations does not describe a unique property. For instance, how should we qualify an item of information supported by several sources of information which is also conflictual with some already registered information? According to STANAG definitions, this item should be given a rating of 1 and should also be given a rating of 5.

Furthermore, according to the recommendations, a rating of 6 should be given to an item whose truth cannot be judged. This suppposes that the other ratings (1...5) concern the evaluation of the truth of information. If so, the rating of 1 should be given to a true information. But, as it is defined, the rating of 1 is given to an item supported by at least two sources. This is questionable since, the different sources (even if they agree) may emit false information.

However, even if the previous recommendations can be criticized, we can see that they present three basic concepts that present a cornerstone in evaluation system. These concept are the following:

- the reliability of a source
- the number of independent sources that support an information
- the fact that the information tends to conflict with some available information.

It is clear that these three concepts are independent. and that they have to be included in all quotation systems, whether these systems are automatic or not.

3.0 ANALYSIS OF THE DIFFERENT EVALUATION CONCEPTS

As it was noticed above three basic concepts are underlying the operational notion of quotation.

Nevertheless, these concepts are used, in the STANAG, in an operational framework which is not necessarily usable in an automatic process. For this reason, we try in this section to give a more comprehensive and formal definitions of these concepts with the aim of using them in an automatic process of fusion.

- ***Reliability***

In mathematical logic, the reliability of a source is defined in a binary way as follows: *an information source is (totally) reliable if and only if the information it delivers are true in the real world.* For instance, a sensor which measures the temperature is totally reliable if and only if the temperature it indicates is the correct one; a human expert is totally reliable if and only if any information (opinion, conjecture etc) he gives is true.

According to the recommendations of STANAG 2022, , the reliability of a source is not a binary notion but a graded one and is defined in reference to its use in the past. It can be measured for example, as the ratio of the number of times the source gave a true information to the number of times it gave information. However, this definition does not take into account the actual environment of use of the information source. For instance, even if it is known to be reliable, an infra-red sensor loose reliability when it rains. So we have to take into account the condition in which the source is used. Some practical consideration of the use of this notion in a numerical context can be find in [7], [8].

However, it must be noticed that there is no consensus yet on a formal definition of reliability. For instance, we can read in the APJ 2.1 "*every piece of information produced by an impeccable source is not necessarily correct".* If "impeccable" intends to mean "reliable", this sentence is contradictory with the definition given previously. Here, it implies that the reliability of a source is not defined by its ability to deliver truth and that even a reliable source can be wrong. But it can be wrong not because it is not sincere but because its model of discernment is maybe not precise enough to distinguish true from false.

- ***Independence***

This notion have to be a little bit enlightened. The classical statistical definition of the independence of two events is given by the rule:

two events A and B are independent iff $P(A,B)=P(A)P(B)$

The STANAG highlights the independence of sources to confirm information. Indeed this independence is important if we want to improve our confidence in a decision when many sources agree on the same decision. However this condition on independence is not sufficient. Let us consider n sources given a

decision about an hypothesis H_i. Our confidence that this hypothesis is true given the fact that the n sources agree on the fact that this hypothesis is true is given by the probability: $P(H_i/d_1=i, \ldots,d_n=i)$ this probability may be written in terms of elementary probability of each source by the formula:

$$P(H_i / d_1 = i,\ldots, d_n = i) = \frac{P(d_1 = i,\ldots, d_n = i/H_i)P(H_i)}{P(d_1 = i,\ldots, d_n = i)}$$

For the sake of simplicity if we suppose that elementary sources are independent, then the above formula may be written as:

$$P(H_i / d_1 = i,\ldots, d_n = i) = \frac{\prod_j P(d_j = i/H_i)P(H_i)}{\prod_j P(d_j = i)}$$

Furthermore if we suppose that each source has the same performance, it is easy to see that this probability is higher than the probability that the hypothesis is true given only one source if and only if each of the source is informative:

$$P(d_j=i/H_i)\hat{}P(d_j=i)$$

This means that the probability of giving a right decision for a given hypothesis is higher than the probability of giving the same decision no matter what is the hypothesis.

- ***Conflict***

In this part we address the concept of conflict with a focus on it use in a symbolical.

In mathematical logic, conflict is defined by the notion of contradiction. *Some pieces of information, i.e, some formulas, are conflictual if and only if, they are contradictory (i.e, there exists no possible world in which they are all true).* For instance, “the object is a plane”, “the object is an helicopter” are two conflictual pieces of information (given the background knowledge that no object can be both a plane and an helicopter). “its speed is 600kmh” “its speed is 625kmh” are also are two conflictual pieces of information (since obviously, not both of them can be true).

However, it seems that the STANAG recommendations want to make a distinction between information which are conflictual and information which tend to be in conflict.

The notion of conflict may be related to the notion of distance between information. In logic an information is modelised by a propositional variable. Then the conflict between tow information may be modelised by a distance which is null if the propositional formulas are not in conflict and different of zero if they are.

In the following we give some definition and property of the notion of distance in the context of logic for dealing with the credibility given in the STANAG.

definition

Let $\mathcal{L}$ a propositional language on a finite alphabet of propositional variables $\mathcal{P}$. An interpretation is a mapping from $\mathcal{P}$ toward $\{0,1\}$. The set of all the interpretation is write W. An interpretation I is a model of a formula if and only if this formula is true for this interpretation. Let w define a formula and mod(w) is the set of model of w. That is $mod(\varphi)=\{I \in \mathbf{W} / I \models \varphi\}$.

Let us now define a distance between two interpretations. This is a function d : W×W →N such that:

$$d(I,J) = d(J,I)$$

$$d(I,J) = 0 \text{ if } I=J$$

This notion helps us to naturally define a distance between an interpretation and a propositional variable by:

$$d(I,\varphi) = \min_{J \models \varphi} d(I,J)$$

Now it is possible to extend this definition to the distance between an interpretation and a set of propositional variables. For this, we have to introduce an operator for the combinatory of the elementary distances. The choice of this operator is outside the scope of this paper and we only focus here on two operator: sum and max. With these operators the distances are given by:

$$d_s(I,\psi) = \sum_{i=1}^{n} d(I,\varphi_i) \text{ for the sum operator}$$

$$d_M(I,\psi) = \mathop{\mathrm{Max}}_{i=1,\dots,n} d(I,\varphi_i) \text{ for the max operator}$$

With $\psi = \{\varphi_1, \dots, \varphi_n\}$

In the symbolical formalism, the simplest distance that it is possible to define between two interpretations is the drastic distance. This distance gives 0 if the two interpretations are equal and 1 if not.

$$d_D(I,J) = \begin{cases} 0 & \text{si } I = J \\ 1 & \text{sinon} \end{cases}$$

In this case the distance between an interpretation and a set of logical proposition is also equal to 0 or 1.

Given w and w' two models of a formula, the number of propositional letter whose valuation differs from w to w' is called the hamming distance.

4.0 EXAMPLE FOR A FORMAL MODEL OF EVALUATION FOR SYMBOLICAL INFORMATION

In this paragraph, we give some ideas on how an evaluation as close as possible to the one recommended by the STANAG may be use when dealing with symbolical information The fusion process we illustrate on an example takes into account the number of the sources that support an information, their reliability. However it does not take into account a graded notion of conflict.

- ***Classical fusion operator***

We recall here some definitions introduced by Konieczny and Pino-Pérez [2], [3] in the context of fusion of database.

Let db1...dbn be n sets of information and Poss be a set of models. Konieczny and Pino-Pérez defined a majority merging operator, denoted Δ such that the set of models of the information source which is obtained from merging db1... dbn with this operator, $Mod((\Delta([db_1,...,db_n])))$, is semantically characterized by:

$$Mod(\Delta([db_1,...,db_n])) = \min_{\leq[db_1...db_n]}(Poss)$$

where ≤[db1…dbn] is a total pre-order on Poss defined by :

$$w \leq_{db_1...db_n} w' \text{ iff } \mathrm{d}(\mathrm{w},[\mathrm{db}_1...\mathrm{db}_\mathrm{n}]) \leq \mathrm{d}(\mathrm{w'},[\mathrm{db}_1...\mathrm{db}_\mathrm{n}])$$

with

$$d(w,[db_1...db_n]) = \sum_{i=1}^{n} \min_{w' \in Mod(db_i)} d(w,w')$$

where d(w,w') is the Hamming distance. In other words, when merging db1...dbn with the operator Δ, the result is semantically characterized by the models in Poss which are minimal according to the pre-order $\leq_{[db_1,...,db_n]}$.

- ***Fusion operator with reliability of the sources***

Here, we to extend this operator by taking a weighted sum instead of the sum.

We assume now that any db_i is associated with a weight, i.e, an integer denoted $r(db_i)$ representing its degree of reliability. For instance, a source whose reliability is A (resp, B, C, D) will be weighted by 5 (resp, 4, 3, 2, 1).

We define Δ_{WS} by :

$$Mod(\Delta_{WS}([db_1,...,db_n])) = \min_{\leq^{WS}_{[db_1...db_n]}}(Poss)$$

$\leq^{WS}_{[db_1...db_n]}$ is a total pre-order on Poss defined by:

$$w \leq^{WS}_{[db_1...db_n]} w' \text{ iff } d_{WS}(w,[db_1...db_n]) \leq d_{WS}(w',[db_1...db_n])$$

with

$$d_{WS}(w,[db_1...db_n]) = \sum_{i=1}^{n} \min_{w' \in Mod(db_i)} d(w,w').r(db_i)$$

i.e

$$d_{WS}(w,[db_1...db_n]) = \sum_{i=1}^{n} r(db_i). \min_{w' \in Mod(db_i)} d(w,w')$$

- ***Example 1***

We consider that the problem consists in identifying a flying object. This object can be a plane (p) or an helicopter (h) or a missile (m). Assume we have five information sources called One, Two, Three, Four and Five whose reliability are respectively A, B, C, D and A. We consider the following flow of information:

- One emits $p \vee h$
- Two emits $h \vee m$
- Three emits p
- Four emits h
- Five emits p.

The questions that raise are: is the object a plane? is the object an helicopter ? is the object a missile ?

By the previous definitions, we can define:

$$\begin{aligned}
&db_1 = \{p \vee h\} \text{ and } r(db_1) = 5\\
&db_2 = \{h \vee m\} \text{ and } r(db_2) = 4\\
&db_3 = \{p\} \text{ and } r(db_3) = 3\\
&db_4 = \{h\} \text{ and } r(db_4) = 2\\
&db_5 = \{p\} \text{ and } r(db_5) = 5
\end{aligned}$$

The three possible worlds are:

$$\begin{aligned}
&w_1 = \{p, \neg h, \neg m\} \text{ in which the object is a plane,}\\
&w_2 = \{\neg p, h, \neg m\} \text{ in which the object is an helicopter,}\\
&w_3 = \{\neg p, \neg h, m\} \text{ in which the object is a missile}
\end{aligned}$$

Then we can compute the following distances:

$$\begin{aligned}
&d_{WS}(w_1, [db_1 \ldots db_5]) = 12\\
&d_{WS}(w_2, [db_1 \ldots db_5]) = 16\\
&d_{WS}(w_3, [db_1 \ldots db_5]) = 30\\
&\text{then } Mod((\Delta([db_1, \ldots, db_5]))) = w_1 = \{p, \neg h, \neg m\}
\end{aligned}$$

It means that, given the information transmitted until now by the different sources and given their reliabilities, the most plausible answer to the query “what is the object?” is “the object is a plane”.

- ***Example 2***

Now, let us consider that the previous information sources have different degrees of reliability, for instance:

$$\begin{aligned}
&r(db_1) = 2\\
&r(db_2) = 5
\end{aligned}$$

$$r(db_3) = 2$$
$$r(db_4) = 5$$
$$r(db_5) = 2$$

And suppose that the five sources send the same information as before.

Then the distances are now the following:

$$d_{WS}(w_1, [db_1 ... db_5]) = 20$$
$$d_{WS}(w_2, [db_1 ... db_5]) = 8$$
$$d_{WS}(w_3, [db_1 ... db_5]) = 16$$

which give as a result: "it is an helicopter".

This example shows the impact of the reliability of the sources in the result of the decision: changing reliability degrees of the sources may lead to different results.

5.0 DISCUSSION

This work intended to formalize some informal recommendations about information evaluation in information fusion. Some of the informal notions underlying the recommendations have been given a formal interpretation, even if, as it has been shown, no consensus exist yet on these definitions and more work is needed. Based on this formalization, we have suggested to implement the fusion process by a weighted majority because this fusion operator takes into account the number of the sources and their reliability. If the number of the sources had not been so important, we could have chosen a method taking into account the reliability of the sources only (see [4], [5], [6] for instance).

However, some of the notions underlying the STANAG recommendations have not yet been taken into account.

For instance, in classical literature, we made no difference between ``being conflictual'' and ``tending to be conflictual''. This last notion assumes that there is a scale for defining conflicts. Generally, this scale is binary and the formal notion which represents the conflict is the logical inconsistency. Extension to graded conflict may be modeled thank to the definition of distance between interpretation but further work have to be made to go closer to the STANAG recommendation.

Another point which has been left aside is the total ignorance about the reliability of a given source, which was a case foreseen in the recommendations. In the present formalization, it seems difficult to represent that. Indeed, which number can be attached to a source whose reliability is not known? That is an open question.

6.0 REFERENCES

[1] Annex to STANAG 2022 (Edition 8). North Atlantic Treaty Organization (NATO) Information Handling Services, DODSID, Issue DW9705.

[2] S. Konieczny and R. Pino-Pérez. On the logic of merging. In Principles of Knowledge Representation and Reasoning (KR'98), pages 488--498, 1998.

[3] S. Konieczny and R. Pino-Pérez. Merging with Integrity Constraints In Proceedings of ESCQARU'99.

[4] C. Baral and S. Kraus and J. Minker and V.S. Subrahmanian. Combining multiple knowledge bases. IEEE Trans. on Knowledge and Data Engineering, 3(2), 1991.

[5] L. Cholvy. Proving theorems in a multi-sources environment. Proceedings of IJCAI, 1993.

[6] C. Liau. A conservative Approach to Distributed Belief Fusion. Proceedings of FUSION, 2000.

[7] V. Nimier « Supervised Multisensor tracking algorithm », FUSION-98, International Conference on Multisource-Multisensor Information Fusion, Las Vegas, USA, July 6-9, 1998, pp 149-156.

[8] V. Nimier, « Introducing Contectual Information in Multisensor tracking Algorithms » Advances in intelligent Computing, Springer, 1994.

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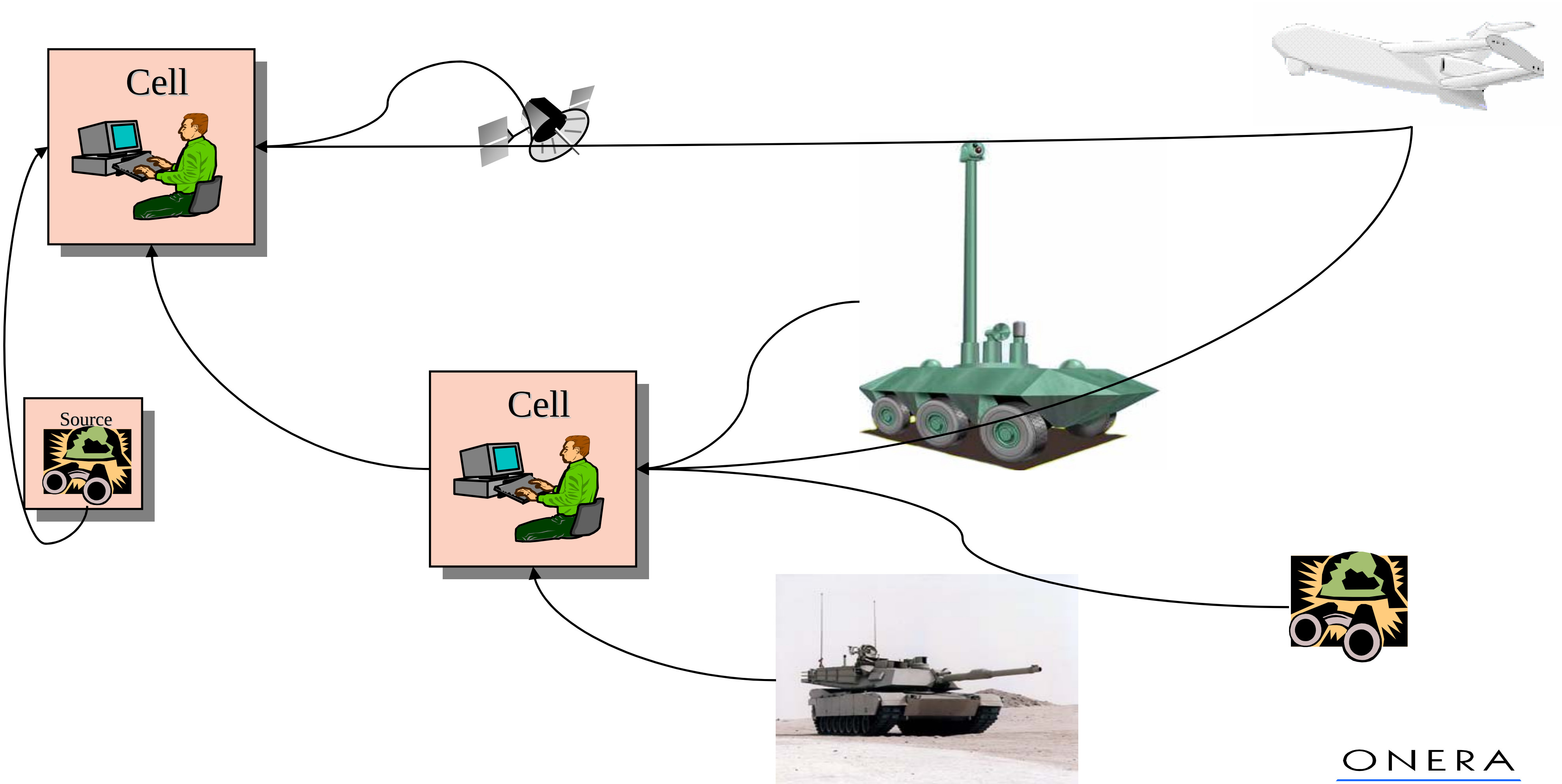
Problem



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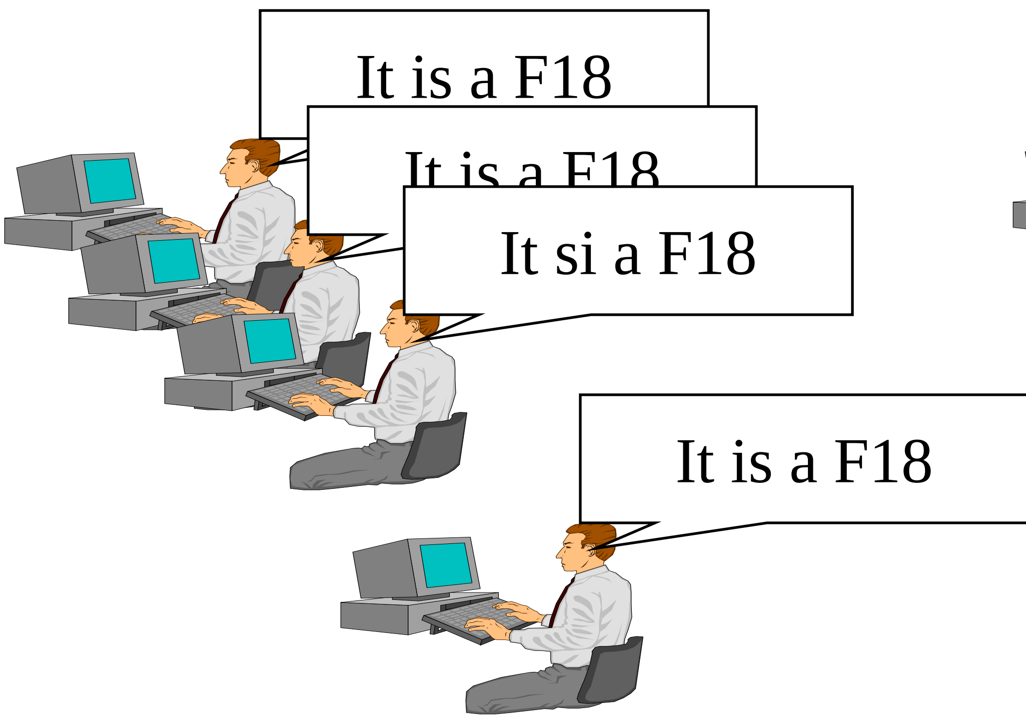
Why fusion ?

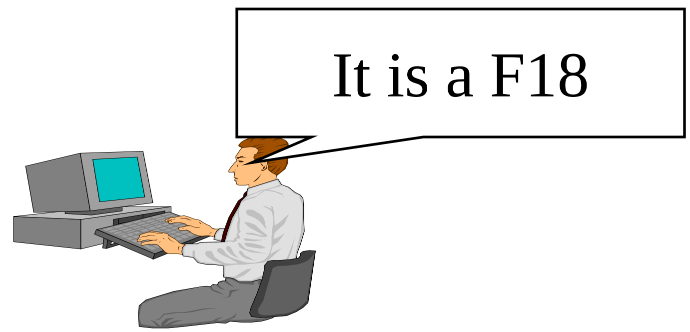
To obtain a reliable et **accurate** information in all conditions of observation

The problem is that all information collected is not of a perfect accuracy or reliability

Objective of data fusion

Suppose all sources are perfectly accurate and reliable

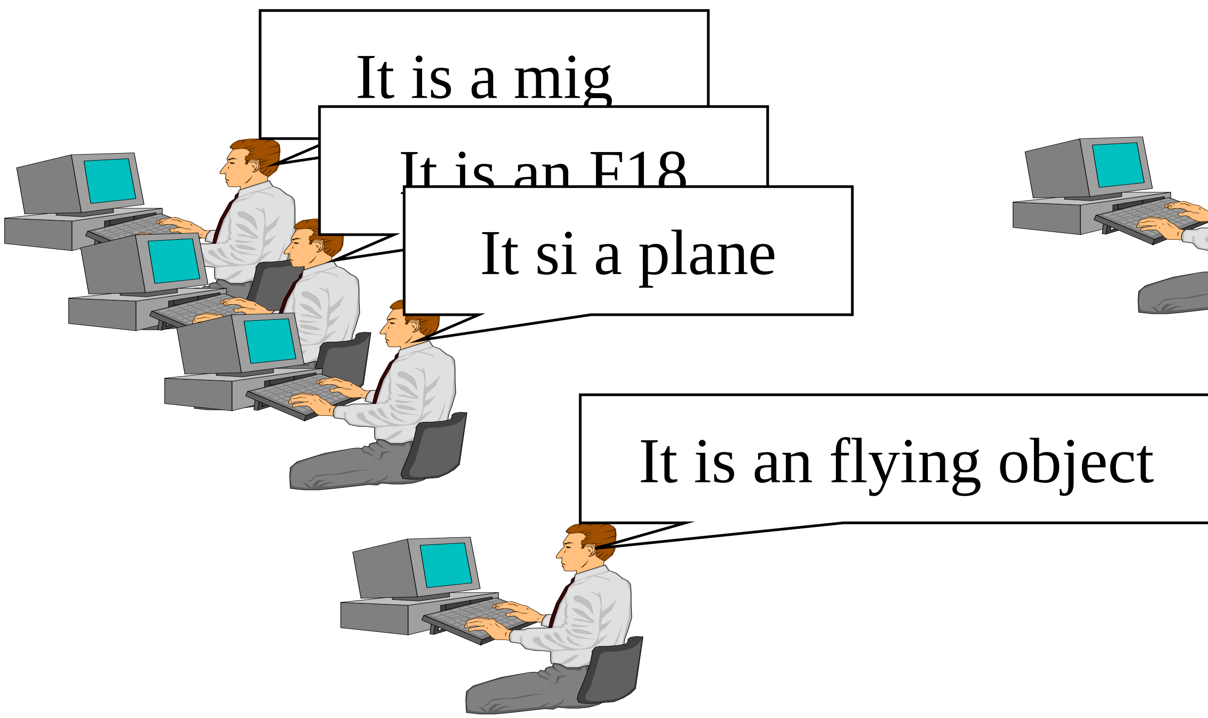


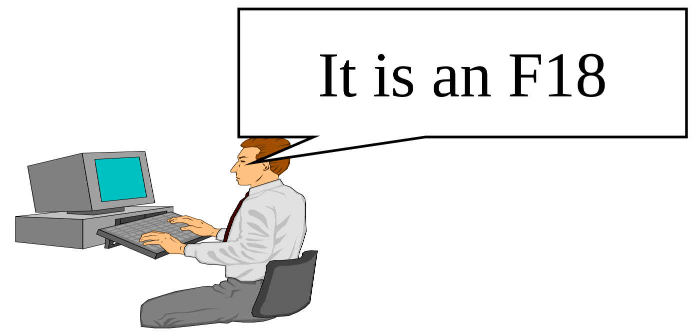


FUSION is not necessary

Objective of data fusion

To obtain a reliable et accurate information in all conditions of observation





Need for a FUSION

Difficulties

The first difficulty Is that the frame of discernment of the source may be very different

- MTI Radar : wheeled vehicle, rotating blades, armored vehicle
- ESM : PR4G, Radar, …
- Humint : ……

The second difficulty is that there is no general framework to deal with the evaluation of the uncertainty of an information

Objective here

Our purpose here address only the issue of improving the reliability of information through fusion. That is, we want a true information, one which is a good representation of the reality.

The problem of accuracy is related to that ofTaxonomie/Ontologie

Existing frameworks

Usually two different frameworks exist depending on the nature of the data but above all on the mathematical culture of the researcher who is dealing with

Numerical data: generally provided by sensor

The techniques to deal with are: probability, possibility theory, Dempster-Shafer theory

Symbolical data: generally provided by Human

The techniques to deal with is : logic, …

The road map for automatic evaluation

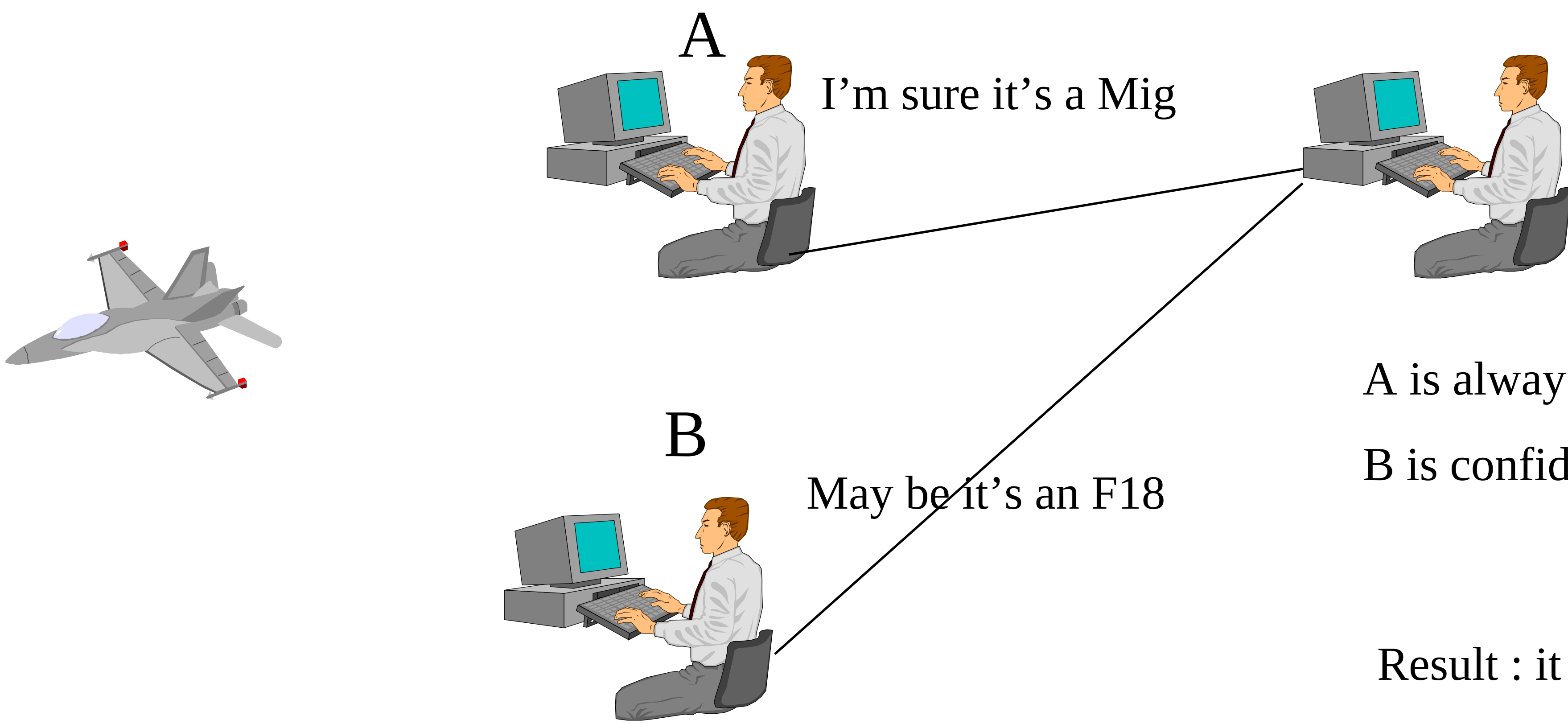
Stanag 2022 give some road map to evaluate data whatever the provider (sensor or humint) but need some human expertise to deal with.

This stanag is well adapted for human treatment of information but needs some mathematical formalism to be included in an automatic treatment

It distinguishes two types of evaluation:

- the reliability of a source
- the credibility of an information

Evaluation of information



A is always wrong

B is confident

Result : it is an F18

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Operational quotation
Stanag 2022, AJP 2.1

Reliability of the Source

A : Completely reliable

B : usual reliable

C : fairly reliable

D : unusual reliable

E : unreliable

F : reliability cannot be judged

Credibility of the information

1: Confirmed

2 : probably true

3 : possibly true

4 : doubtful

5 : improbable

6: credibility cannot be judged

Reliability

Reliability of the sources : In order to qualify the source reliability, STANAG 2022 recommends to use letters A…F, so that :

a source is evaluated A if it is completely reliable (it refers to a tried and trusted source which can be depended upon with confidence)

a source is evaluated B if it is usually reliable (it refers to a source which has been successfully used in the past but for which there is still some element of doubt in particular case)

a source is evaluated C if it is fairly reliable (it refers to a source which has occasionally been used in the past and upon which some degree of confidence can be based)

a source is evaluated D if it is not usually reliable (it refers to a source which has been used in the past but has proved more often than not unreliable)

a source is evaluated E if it is unreliable (it refers to a source which has been used in the past and has proved unworthy of any confidence)

a source is evaluated F if its reliability cannot be judged (it refers to a source which has not been used in the past)

Credibility

Credibility of the information : In order to qualify the information credibility, STANAG 2022 recommends to use numbers 1…6 so that :

a piece of information is evaluated 1 (Confirmed) if it is confirmed by others

a piece of information is evaluated 2 (probably true) if its likelihood is regarded as sufficiently established

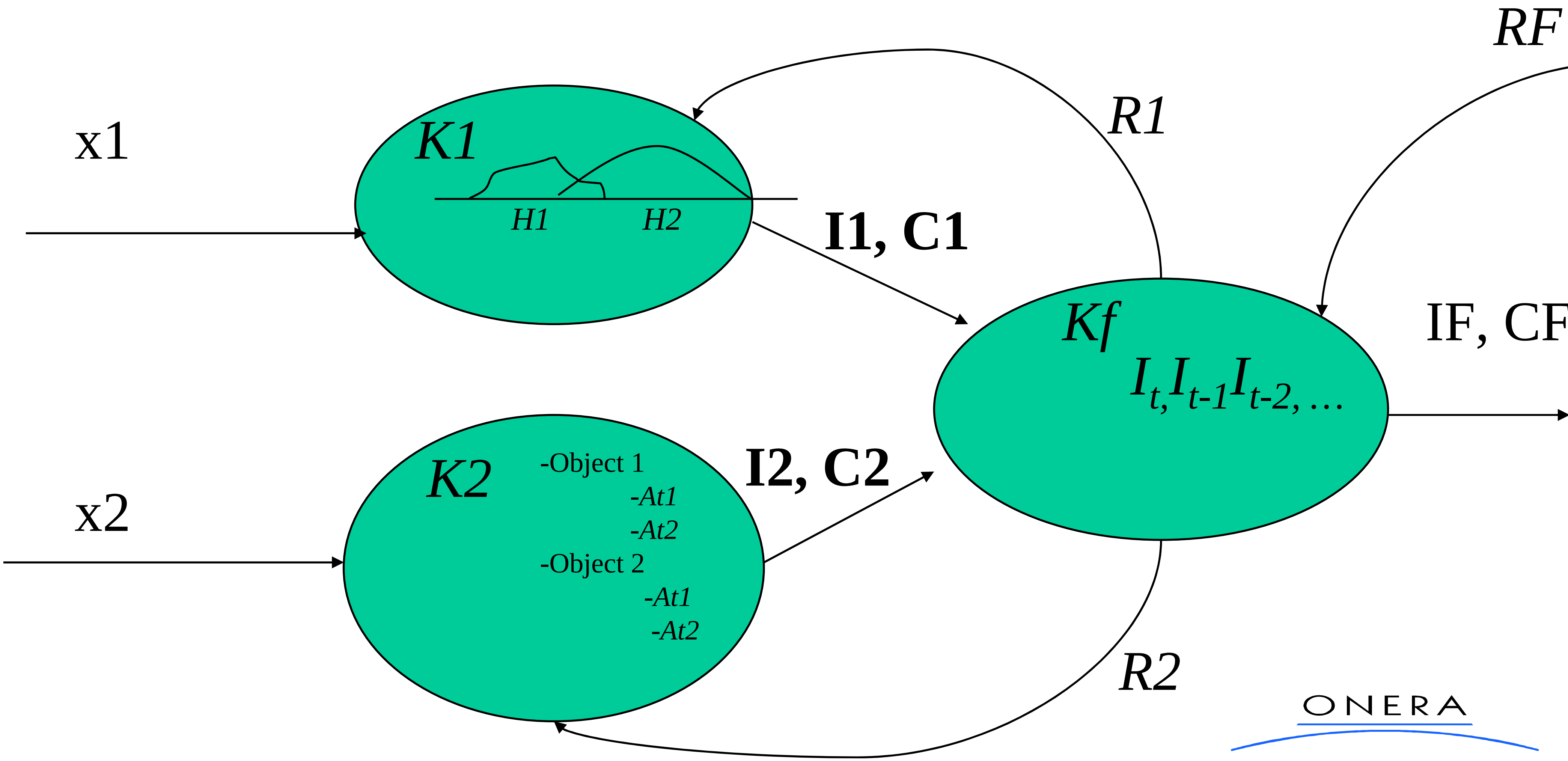
a piece of information is evaluated 3 (possibly true) if it does not conflict with previous information

a piece of information is evaluated 4 (doubtful) if it tends to conflict some previous information

a piece of information is evaluated 5 (improbable) if it positively contradicts previous information

a piece of information is evaluated 6 if its truth cannot be judged

Model


x1
K1
H1
H2
R1
RF
I1, C1
Kf
$I_{t,}I_{t-1}I_{t-2, \ldots}$
IF, CF
x2
K2
-Object 1
-At1
-At2
-Object 2
-At1
-At2
I2, C2
R2

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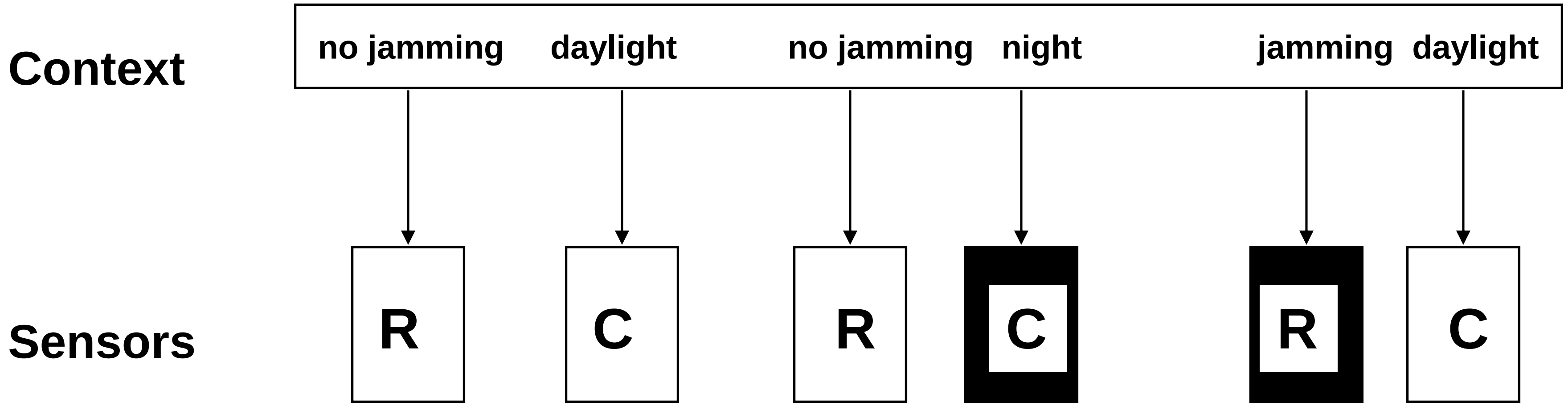
Three different notions

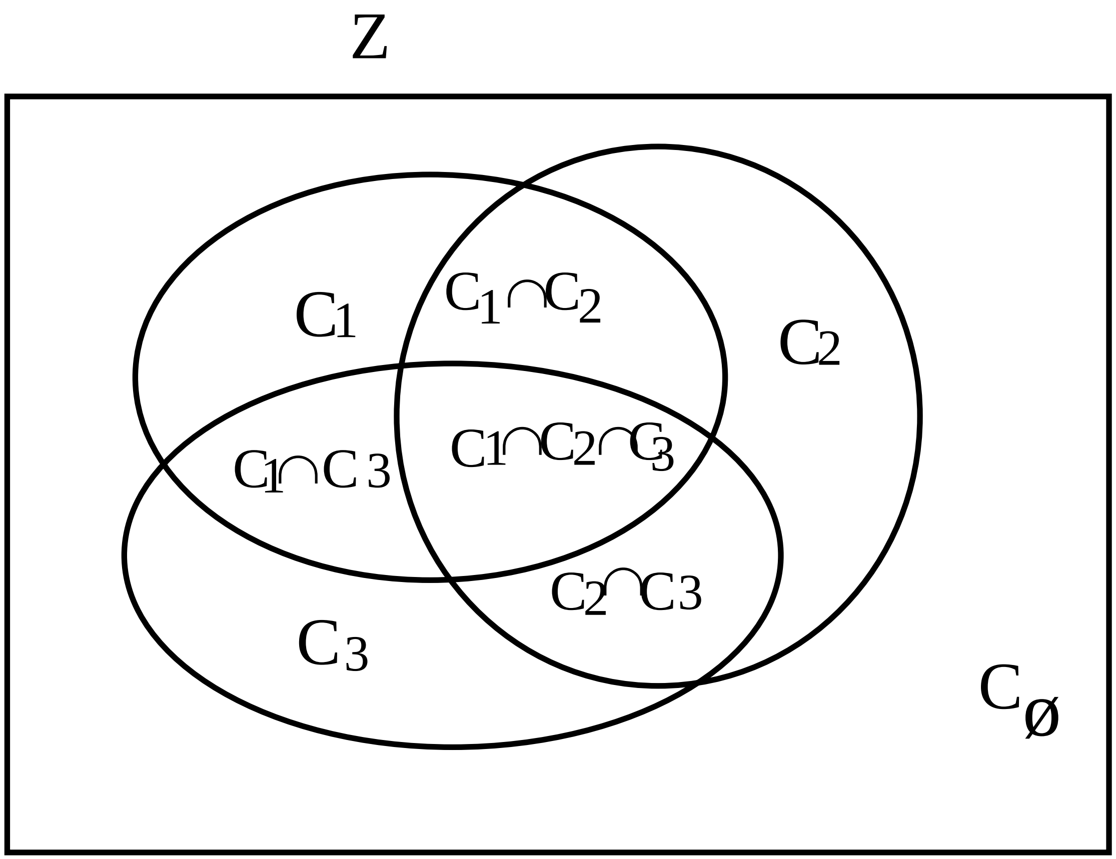
- **Reliability of a source**
- **Credibity of information**
  - Independence and the number of the sources
  - Conflict of an information

Reliability of a source

It is dependent on of the ability of a source to give a true information in a particular context of uses

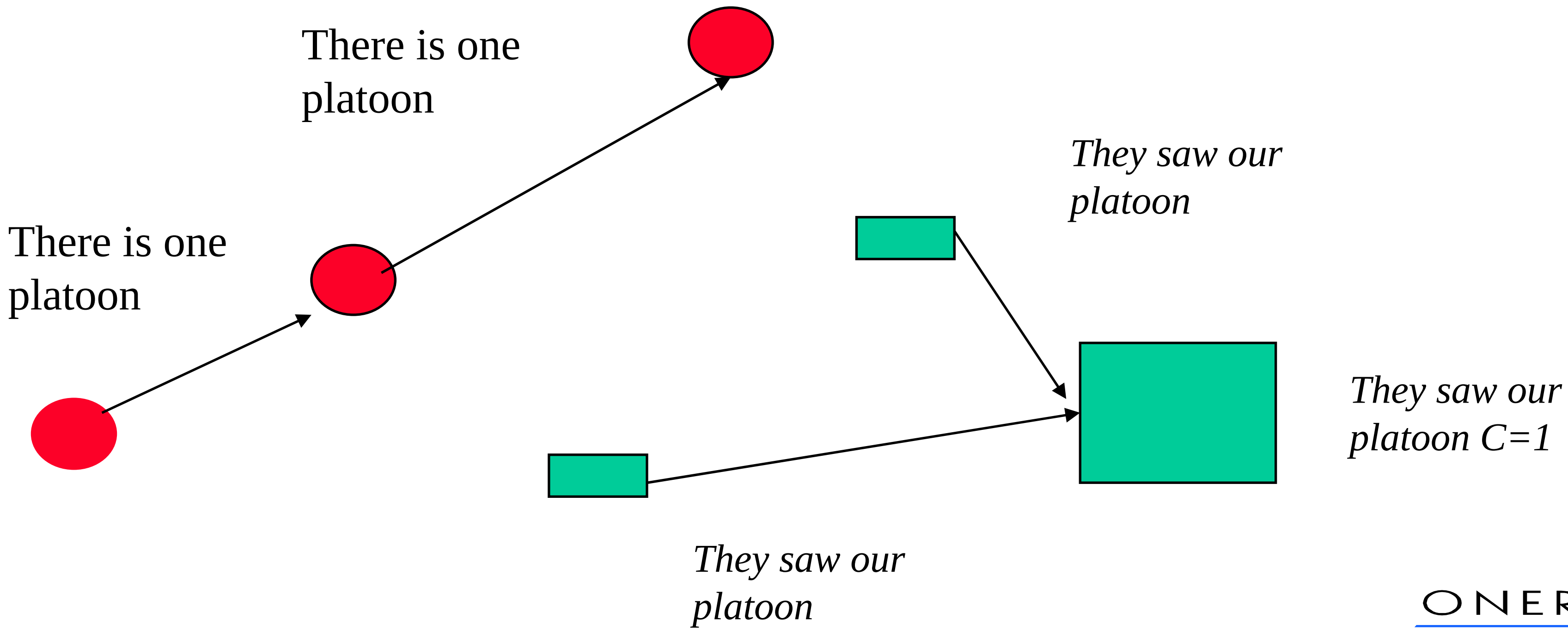


CONTEXTUAL SPACE



Independence

The sources have to be independent an the object observed have also to be unique (physical object)



Credibility of information

We have to define the notion of conflict. This notion is closely related to the notion of the distance a source may have between the data it received and the model it has.

- **Numerical**: it is given by the probability/possibility of the data received given each hypothesis

  P(x/H1), P(x/H2), ….. ,P(x/Hn)

- **Symbolical:** it is given by the distance between interpretation

  Example : the Hamming distance between two interpretations w and w' of a formula is the number of propositional letters which are true in w and false in w'.

A mathematical model for credibility in relation with the stanag 2022

Closed Word assumption: all the hypotheses are known by the user.

In that case, without any information but a priori information all hypotheses are possible so their credibility is equal to 3 : possible

If one information is given by a source that confirms one of the hypotheses then this hypothesis has a credibility of 2 : probable (it is not confirmed) and the other has the credibility of 4 (doubtful)

If two or more information are given by different and independent sources that confirm one hypothesis then the credibility of this hypothesis is 1 (confirmed) and the credibility of the other is 5 (improbable)

A mathematical model for credibility in relation with the stanag 2022 (possibility theory)

Thank to the possibility theory and the relation $\Pi(H_i)= 1 - N(\neg H_i)$

Π(Hi) =1 N(Hi)=1 then the credibility is equal to 1 “confirmed”

Π(Hi) =1 0<N(Hi)<1 then the credibility is equal to 2 “probable”

Π(Hi) =1 N(Hi)=0 then the credibility is equal to 3 “possible”

0<Π(Hi)<1 N(Hi)=0 then the credibility is equal to 4 “doubtful”

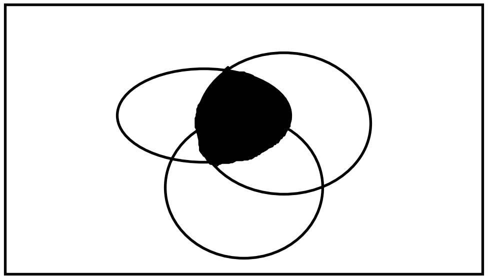
Π(Hi) =0 N(Hi)=0 then the credibility is equal to 5 “improbable”

Use of evaluation in a fusion process (numerical)

System N = {1,2,3}

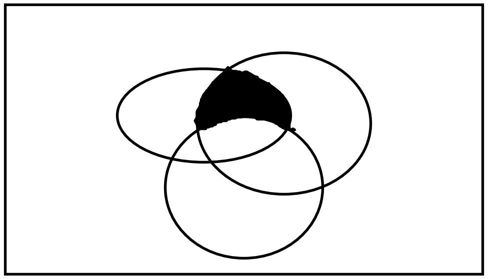
Association of sensors J = {1,2}

Inclusive probability



$$P(C_i \cap C_j) = \int Min(\mu_i(y), \mu_j(y))P(y)dy$$

Exclusive probability



$$\beta_J = P(c_J) = \sum_{\{I \subseteq N / J \subseteq I\}} (-1)^{|I-J|} P(\bigcap_{i \in I} C_i)$$

STATIC ESTIMATION

Minimum Mean Square Error Estimation

$$\hat{x} = E(x/Y) = \int xP(x/Y)dx$$

Total Probability Theorem

$$P(x/Y) = \sum_{J \subseteq N} P(x/Y, c_J)P(c_J)$$

Estimation

$$\hat{x} = \sum_{J \subseteq N} \beta_J E(x/Y_J)$$

Use of evaluation in a fusion process (symbolical)

Let mod(φ)={I$\in$W / I $\models\varphi$} be the set of models with I an interpretation

Given a distance d between interpretation : W×W $\rightarrow$N such that:

d(I,J) = d(J,I)

d(I,J) = 0 if I=J

A distance between an proposition and an interpretation is given by

$$d(I,\varphi) = \min_{J \models \varphi} d(I,J)$$

Use of evaluation in a fusion process (symbolical)

The distance between an interpretation and a set of propositions is given by

$$d_{WS}(w,[\varphi_1 \ldots \varphi_n]) = \sum_{i=1}^{n} \min_{w' \in Mod(\varphi_i)} d(w,w').r(\varphi_i)$$

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Example

p= plane, h= helicopter , m=missile

- **Source One emits p $\vee$ h**
- **Source Two emits h $\vee$ m**
- **Source Three emits p**
- **Source Four emits h**
- **Source Five emits p**

The questions are:

- **is the object a plane ?**
- **is the object an helicopter ?**
- **is the object a missile ?**

Example

$$\varphi_1 = \{p \vee h\} \quad r(\varphi_1) = 5$$
$$\varphi_2 = \{h \vee m\} \quad r(\varphi_2) = 4$$
$$\varphi_3 = \{p\} \quad r(\varphi_3) = 3$$
$$\varphi_4 = \{h\} \quad r(\varphi_4) = 2$$
$$\varphi_5 = \{p\} \quad r(\varphi_5) = 5$$

Example

$$w_1 = \{p, \neg h, \neg m\}$$

$$w_2 = \{\neg p, h, \neg m\}$$

$$w_3 = \{\neg p, \neg h, m\}$$

$$d_{WS}\left(w_1, \lfloor \varphi_1 \ldots \varphi_5 \rfloor\right) = 12$$

$$d_{WS}\left(w_2, \lfloor \varphi_1 \ldots \varphi_5 \rfloor\right) = 16$$

$$d_{WS}\left(w_3, \lfloor \varphi_1 \ldots \varphi_5 \rfloor\right) = 30$$

$$\mathrm{Merge}(DB) = w_1 = \{p, \neg g, \neg m\}$$

Conclusion

We have placed emphasis on the evaluation process on data fusion.

- We have to define two quantities : the credibility of information and the reliability of the source
- This mathematical definition of these quantities must have a real correspondence with the heuristic but operational definition given in stanag 2022
- We have given an example of how using such an evaluation in a fusion process with symbolical data. Other works exist for numerical data

Further works have to be made on general and coherent definition of the notion of conflict (distance) whatever the type of data manipulated (numerical, symbolical) in a general framework (Dempster-Shafer)

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